PSO based Power Allocation for Single and Multi Relay AF Cooperative Network

A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

Master of Technology

in

Electronic Systems and Communication

By

AKHIL DUTT TERA

212EE1215

Department of Electrical Engineering

National Institute Of Technology

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Under the Guidance of

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Dedicated to my family,

Supervisor and my friends

DEPARTMENT OF ELECTRICAL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY, ROURKELA

ROURKELA- 769008, ODISHA, INDIA

Certificate

This is to certify that the dissertation work entitled "**PSO based Power Allocation for Single and Multi Relay AF Cooperative Network"** is a bonafied work carried out **by Akhil Dutt Tera (212EE1215)** during 2013-2014, under my supervision and guidance in partial fulfilment of the requirement for the award of the degree of Master of Technology in Electrical Engineering (Electronic Systems and Communication), National Institute of Technology, Rourkela.

Place: NIT Rourkela

Date: -----May 2014

Prof. Susmita Das

Dept. of Electrical Engineering

NIT Rourkela

DEPARTMENT OF ELECTRICAL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY, ROURKELA

ROURKELA- 769008, ODISHA, INDIA

Declaration

I certify that

i. The work carried out in this thesis is original and has been done by myself under the guidance of my supervisor

ii. For writing the thesis, I followed the guidelines provided by institute.

iii. Whenever i used content in this thesis from other source, I have given due credit to them by citing them in the text of the thesis and giving their details in the references

iv. The work has not been submitted to any other Institute for any degree.

Akhil Dutt Tera

Dept. of Electrical Engineering

NIT Rourkela

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Akhil Dutt Tera.

Roll No: 212EE1215

Dept. of EE, NIT, Rourkela.

ABSTRACT

Wireless channels are generally suffering from fading. Diversity is the effective way to combat fading in wireless channels. But, the ultimate aim of diversity is to allow multiple antennas into the environment. Due to size and hardware complexity, many wireless devices are limited to one antenna. Cooperative communication is a new class of diversity, it allows single antenna users into multi user environment to share their antennas and create virtual multiple antennas.

In cooperative communication, the information is transmitted with help of neighboring nodes, which are called relays. Cooperative diversity is based on different relaying schemes such as AF, DF.

Cooperative transmission using relay gives better performance compare to direct transmission between source and destination. The system performance enhances for multi relay model and in addition the diversity order also increased. Power allocation is one of the major issues in a wireless cooperative communication for enhance the system performance. In this work, a single and multi relay cooperative network is considered using amplify-and-forward relaying scheme. Considering the perfect channel state information (CSI), allocating power to source and relay using Particle Swarm Optimization (PSO) with minimizing as a constraint.

The PSO algorithm maintains a group of particles, where each particle in the group gives a possible solution. PSO gives the best optimum value for a given problem by using objective function. Hence the implemented scheme of PSO base power allocation in cooperative network enhances the system performance.

CONTENTS

FIGURES

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ABBREVIATIONS

AF	Amplify and Forward
DF	Decode and Forwards
SER	Symbol Error Rate
CRC	Cyclic Redundancy Check
SNR	Signal to Noise Ratio
CSI	Channel State Information
EGC	Equal Gain Combining
MRC	Maximal Ratio Combining
SC	Selection Combining
M-QAM	M-ary Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
EPA	Equal Power Allocation
OPA	Optimum Power Allocation
PSO	Particle Swarm Optimization

Chapter 1

INTRODUCTION

1 INTRODUCTION

1.1 Overview

Cooperative communication is a new class of diversity; it is used for efficient wireless communication. The basic idea behind the user-cooperation is that of information sharing with multiple nodes in a wireless communication network. The reason beyond is sharing of user cooperation is that desire to share power and data processing with neighboring nodes for effective case of resources. In cooperation the single antenna users share their antennas. So that it improves communication capacity, speed and performance [1].

The main reason behind the invention of cooperative communication is to combat fading in wireless channels. In wireless communication, fading is the fast fluctuations of a transmitted signal over a small period of time. It is caused by the interference among two or more transmitting signals, which are received at the receiver at dissimilar times. Due to loss of information during propagation (because of fading), the system performance degrades. These effects are overcome by cooperative diversity. The cooperation is existing whenever the communicating nodes are more than two, means source, destination and relay.

In cooperative communication, the wireless users, which we called relays, enhance the quality of the system performance in terms of outage, SER or block error rates through cooperation. In this type of communication all the wireless agents transmit information and acts as cooperative agent. The main obstacles of cooperative communication power allocation. In case of transmit power, additional power is required to transmit the information because in cooperation mode each user transmits the data to both users.

To get high data rates, we have to maintain high reliability of the data sent through the communication link is the main objective of any state of communication. However in wireless environment the wireless channels are suffer from unwanted effects e.g., path-loss, shadowing, fading etc. which causes signal strength reduction. Diversity is the best way to overcome these effects, by transmits the multiple copies of same signal over different free channels. In cooperative communication the diversity is achieved by a third node other than source and destination called relay.

The possible solution to reduce channel destruction is diversity. Diversity is used to mitigate such fading effects in communication systems through transmitting signals from multiple antennas, they allowing freely faded version of the signal at destination. The benefits of the MIMO systems have been recognized, and it is proposed to create spatial diversity by provision the wireless systems with multiple antennas. But due to size and hardware complexity wireless devices are limited to only single antenna; the MIMO system not related in this domain. Cooperation produces solution by allowing isolated antenna mobiles into a multi-users environment to create an essential multiple antennas to obtain cooperative diversity. Thus, each device in the network transmits its own data and cooperates in transmitting the information of other users at a same time.

Among all, the basic relaying schemes are AF and DF. AF scheme is low complexity and it is advantageous when the relay is away from destination. AF relaying for single relay and multi relay cases are considered and analyzed in this work.

1.2 Literature Survey

Cooperative communication is a new class of transmission, the basic idea of the cooperation is that signal transmission by neighboring nodes, called relays. Wireless systems are generally suffers from fading. Diversity techniques are used to combat fading via providing spatial diversity. Cooperative diversity can also improve speed, performance and coverage. The main aim of diversity is to allow multiple antennas into wireless environment. But generally many wireless networks are limited to one antenna by size or hardware complication [1].

Cooperative communications allows the single antenna users into multi user domain and share their antennas to create a virtual antenna. Hence cooperative communication efforts the diversity.

Authors in [1] provided a brief description of cooperation in wireless networks and advantages of MIMO systems. The performance of cooperative communication is based on relaying schemes such as AF and DF schemes. In AF relaying, the relay node amplifies the received signal and forward to its destination. Decode and forward relaying is re-encodes the signal, and forwards to its destination. Coded cooperation is modeled by a code design. In coded cooperation each user transmits data in two frames, first frame contains its own data and second frame contains its partner's data. Whenever the cooperation is not possible, the users send its own information in second frame also.

The research on cooperative communication is still necessary to be focused. The advantages of diversity in wireless communication in terms of symbol error rate (SER), power allocation (PA) and space time and error correction coding. The authors in [5] presented an approach for wireless transmission through coded cooperation. In [5] authors descried about coded cooperation for better wireless transmission. In coded cooperation the users are follows the code design. Each user in this method transmits their data by two frames, first frame contains users own information and second frame contains partners information [2-4]. Whenever the cooperation is not possible the users sends its own information in second frame also.

Torabi, Mohammad, WessamAjib, and David Haccoun presented SER performance analysis for amplify and forward relaying under M-QAM and M-PSK modulation in Rayleigh fading channel [6]. They derived moment generating function (MGF) expression for end-to-end SNR. Maximal ratio combining technique is used here to combine the multiple copies of signals at the receiver. Here equal power allocation is applied to source and relay. But due to location of relays and channel condition, it is very difficult to get improved performance with equal power allocation. In cooperative communication, the neighboring nodes (relays) are helpful to transmit the data from source to destination. Power allocation is an important issue in cooperative communication for enhances the system performance in terms of SER , outage [7]. The authors Deng, Xitimin and Alexander M. Hamovichin [7], analyzed a simple power allocation for single relay AF cooperative communication, by considering a amplification factor and allocate power constraint which is multiplied at relay node. They provide performance analysis for only outage probability. However the SER performance also important issue in cooperative communication for increases the system performance [8, 9]. Kwangyul Kim and Yoan Shin introduced PSO based power allocation for single relay DF relaying scheme with knowledge of partial channel state information for increase the system performance [10]. But decode and forward (DF) relaying gives better performance when the relay decodes the received data perfectly and for this complexity is also more. In [11], comparison is carried out between equal and PSO based power allocation. First, obtain the partial channel state information, deriving instantaneous optimum value; evaluate the fitness function using PSO algorithm. Finally the optimum solution is obtained by the help of gbest in PSO.

In wireless environment numbers of relays are present, multi-relay cooperative communication efforts the better diversity gain. Whenever cooperation is carried out it is necessary to allocate power to multi-relay system [12, 13]. Luo, Jianghong, et al are illustrate cooperative relaying using DF in a N-node distributed network, the power allocated among the source and relay for minimizing outage probability [14], however the SER performance also important issue in multi-relay cooperative communication for enhance the system performance and it is need to allocate optimum power allocation for each relay [9].

In this work, multi relay cooperative network using AF relaying is considered. AF relaying gives better performance compare to DF when the relay located away from source (when the relay unable to decode the received data perfectly) and has low complexity. PSO based power allocation is applied for multi relay cooperative network and SER performance is compared for both PSO and equal power allocation scheme.

1.3 Motivation

Cooperative communication provides various advantages over MIMO system. The major concern for the realization of cooperative communication is power allocation (PA). Power allocation is a useful solution to save transmits power and improves the performance of the system. Basically in cooperative communication, the power is allocated to source as well as relay. The problem is how to allocate the power to source node and relay based on link condition and channel state information availability.

1.4 Objectives

The objectives of this thesis are:

1. To study of relaying schemes for various protocols of diversity schemes such as AF and DF.
2. Calculation of SER for single and multi-relay Amplify and Forward (AF) relaying scheme in Rayleigh fading channel.
3. Power allocation for single relay and multi relay AF protocol using equal power allocation.
4. Optimization of power allocation for single relay and multi-relay AF protocol using Particle Swarm Optimization algorithm.

1.5 Thesis Organization

Chapter 1: Introduction

This chapter consists of introduction, motivation and objectives behind the project and literature survey. This brief description about the cooperative communication systems is discussed in this chapter 1.

Chapter 2: Cooperative Communication system- An overview

Chapter 2 describes the basic idea of cooperative communication. It also explains various cooperative diversity strategies and protocols such as AF and DF and coded cooperation. At the receiver the multiple copies of the transmitted information is combined, by using combining techniques such as MRC, EGC, and FRC. Power allocation in cooperative relaying is discussed.

Chapter 3: System Model

This chapter describes the system model and explains the process of diversity system used in the system model. The mathematical expression for AF protocol and its symbol error rate (SER) expression is derived in this section.

Chapter 4: Results and Discussion

In chapter-4, we represent the simulation results of project work. The simulation is carried out in MATLAB. The transmitted power P_t =1 W and source and relay power are 0.5 W each for equal power allocation. The SER performance analysis is obtained by using equal power allocation, after that the optimized power allocation using Particle Swarm Optimization algorithm (PSO) is discussed in this section. Simulation results of both equal and PSO base power allocation are compared in Rayleigh fading channel.

Chapter 5: Conclusion and scope of future work

This chapter gives the outline and conclusion of complete research work, also provides the scope of further possibilities in this work.

Chapter 2

COOPERATIVE DIVERSITY PROTOCOLS

COOPERATIVE DIVERSITY PROTOCOLS

2.1 Introduction

Cooperative diversity is a technique; it allows single antenna users in multi-user wireless environment, to create a virtual multiple antennas. The reason behind the invention of cooperative communication is combating fading and transmits high data rates in wireless communication because wireless systems are generally suffers from fading, diversity is the way to reduce fading, and the ultimate aim of diversity is allow multiple antennas in to wireless environment to send multiple copies signals to destination. But due to size and hardware complexity wireless devices are limited to only one antenna and the MIMO is not related in these cases. Cooperative communication overcomes this problem by allowing the single antenna devices into multi-user environment.

In cooperative communication the information is transmitted with the help of neighboring nodes, which is called relays. The relay is the basic origin for cooperative communication systems. The fundamental cooperative communication network consists of a source, destination and relay. By the help of relaying it is possible to transmit multiple copies of information from source to destination. Sending multiple independent copies of signals reduce the symbol error rate (SER) and probability of error.

2.1.1 Advantages of cooperative relaying

Cooperative communication has several benefits in wireless transmission [23].

1. High diversity gain
2. High throughput and Lower delay
3. Lower interference

1. High diversity gain

In cooperative communication high diversity gain is obtained. The ultimate aim of diversity is to allow more than one antenna into wireless environment; this condition is satisfied in cooperative communication.

2. High throughput and lower delay

High throughput is achieved in wireless systems by cooperative communication because the relays are very helpful in transmitting the data. The multiple relays transmits their partners information to destination by this way it is possible to overcome the high delay in wireless communication.

3. Lower interference

The cooperative communication is also helpful to reduced interference for the cellular based cooperative network to reuse a limited bandwidth. With the advantages of cooperation like throughput, lower delay, the interference in cellular communication is reduced.

2.1.2 Applications of cooperative relaying

Cooperative relaying schemes are widely applied in [22].

1. Virtual antenna array
2. Ad-hoc networks
3. Wireless sensor networks
4. Cognitive radio

1. Virtual antenna array

In wireless communication, MIMO improves the system performance and it is also improves the diversity gain. But due to size and hardware complexity wireless devices are limited to only one antenna and MIMO is not related in these cases. Cooperative communication overcomes this problem by allowing the single antenna devices into multi-user environment and creates a virtual multiple antennas.

2. Ad-hoc networks

The self-organizing networks are called wireless ad-hoc networks. This type of networks doesn't have a specified integrate infrastructure. These types of networks are used in civilian and military communication applications.

3. Wireless sensor networks

By the help of cooperative relaying the energy consumptions decrease and life time increases.

4. C**ognitive radio**

Cognitive radio (CR) is a transceiver system which works on the principle of dynamic spectrum access. The key concept of CR is spectrum sensing. The secondary users (SUs) will sense the spectrum occupancy of the licensed band and leave the spectrum when the licensed user wants its access back. In cooperative cognitive system the SUs will share their sensed data, therefore improving the detection probability**.**

2.1.3 A simplified cooperation model

In this chapter, first a basic cooperative communication model is discussed after that, we discuss various types of cooperative diversity protocols. Consider a simple cooperative model as depicted in Figure 2.1, here the source sending information with transmit power P_1 and P_2 is the relay power [15].

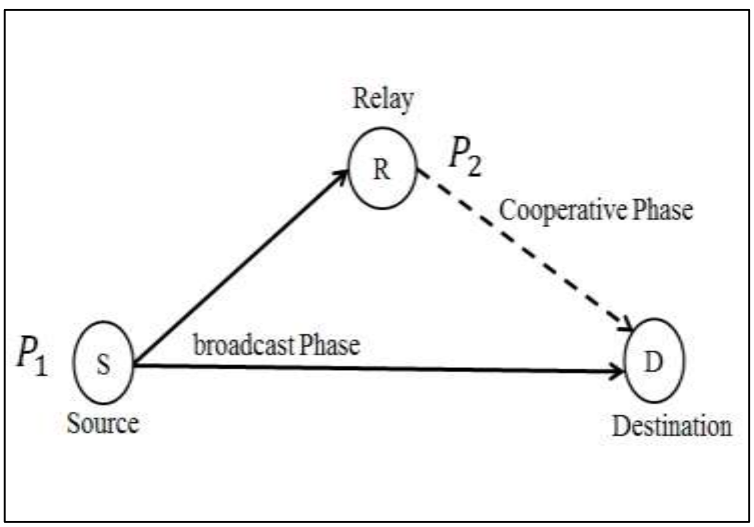


Figure 2. 1 A simplified cooperation model [1]

- In broadcast phase, source broadcast the data to both relay and destination.
- In the cooperative phase, relay forwards the data to destination node.

The received information at destination node $y_{s,d}$ and the relay node $y_{s,r}$ are [15]:

$$y_{s,d} = \sqrt{P}h_{s,d}.x + Z_{s,d}$$

(2.1.1)

$$y_{s,r} = \sqrt{P}h_{s,r}.x + Z_{s,r}$$

(2.1.2)

Here P is the transmitted power, x is the transmitted information, $z_{s,d}$ and $z_{s,r}$ are AWG noise, here $h_{s,d}$ and $h_{s,r}$ are the channel coefficients. These are modeled by zero mean, with variances $\delta_{s,d}$ and $\delta_{s,r}$ respectively.

The received information at the destination $y_{r,d}$ from relay is [15].

$$y_{r,d} = \frac{\sqrt{p_r}}{\sqrt{p_s\left|h_{s,r}\right| + N_0}} h_{r,d}[n].y_{s,r} + z_{r,d}[n]$$

(2.1.3)

2.2 Cooperative transmission protocols

The cooperation planning is based on the different schemes have to come to known as relay schemes or relay protocols. The most commonly used cooperative relaying schemes at the relays are AF, DF and Coded cooperation. AF and DF are mostly common used protocols.

2.2.1 Amplify-and-forward

In AF, the relay is amplifies and forwards the information from the source during broadcast phase and retransmits the signal to its destination during broadcast phase. Each user in this scheme receives a noise type signal transmitted by its neighbor. The received data for the direct link [15].

$$y_{s,d} = \sqrt{P} h_{s,d} . x + Z_{s,d} \tag{2.2.1}$$

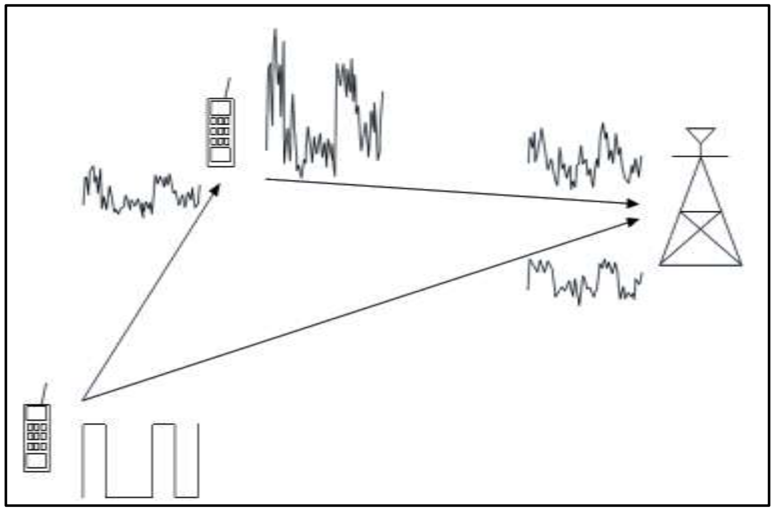


Figure 2. 2 Amplify and forward protocol [1]

Similarly at relay node:

$$y_{s,r} = \sqrt{P} h_{s,r} . x + Z_{s,r} \tag{2.2.2}$$

The relay amplifies the signal with the same power at which the data from the source; hence the relay has to use a gain of [15]

$$\beta_r = \frac{\sqrt{P}}{\sqrt{P \left| h_{s,r} \right|^2 + N_0}} \tag{2.2.3}$$

Thus signal received at the destination [14]

$$y_{r,d} = \frac{\sqrt{p_r}}{\sqrt{p_s \left|h_{s,r}\right|^2 + N_0}} h_{r,d}[n].y_{s,r} + z_{r,d}[n]$$

(2.2.4)

2.2.2Decode-and-forward

In this scheme, the relay receives and re encodes the information and forward to its receiver. After decoding the received signal perfectly the relay re-encodes the decoded signal and forwards to its destination. The signal received at the destination is expressed as [15].

$$y_{s,d} = \sqrt{P} h_{s,d}.x + Z_{s,d}$$

(2.2.5)

In DF protocol, the error correction code in the source information can be corrected at the relay station.

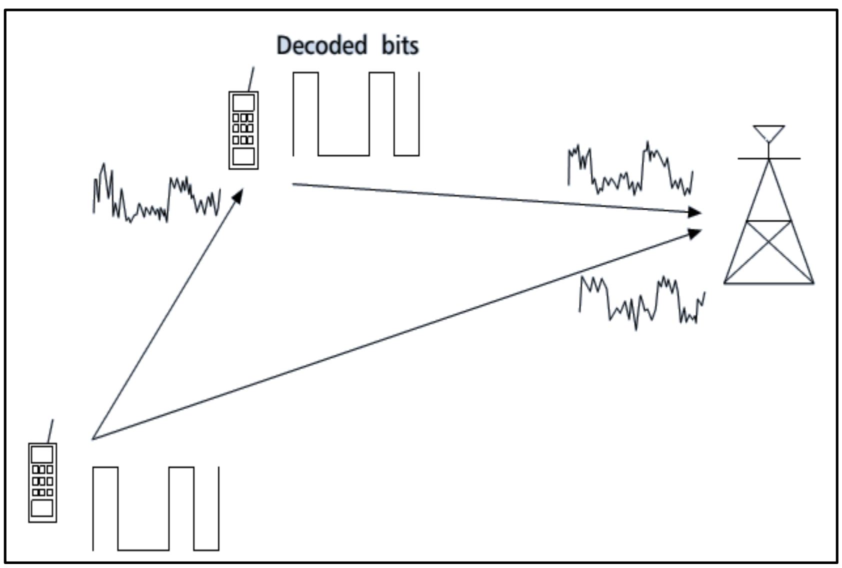


Figure 2. 3: Decode and Forward protocol [1]

2.2.3 Coded cooperation

Coded cooperation integrates cooperation into channel coding. In both AF and DF, the relay repeats the information from the source, to its destination. The idea behind the coded cooperation is re-arranging coded symbols and sending each users code word of different portions. In this scheme each user sends neighbors data by its data stream by second frame. Whenever cooperation is not exist the users stay in a non-cooperative mode automatically.

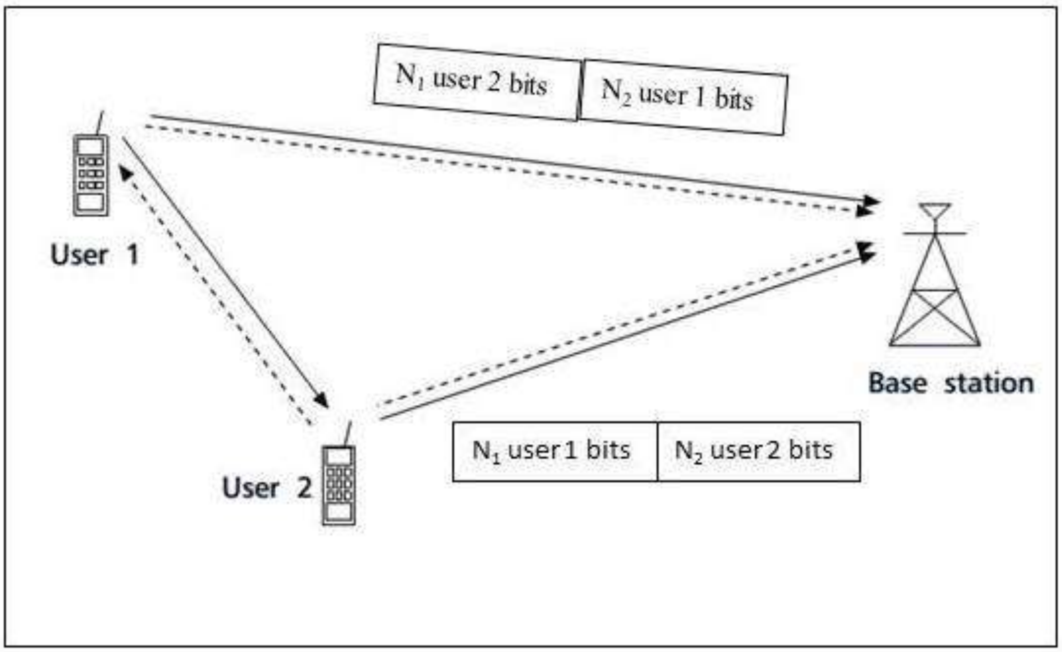


Figure 2. 4: Coded cooperation [1]

In coded cooperation all the process is automatically managed by a code design and no feedback in this scheme. In this scheme, mobile users split the data block into frames. The data is improves with cyclic redundancy check (CRC) [1].

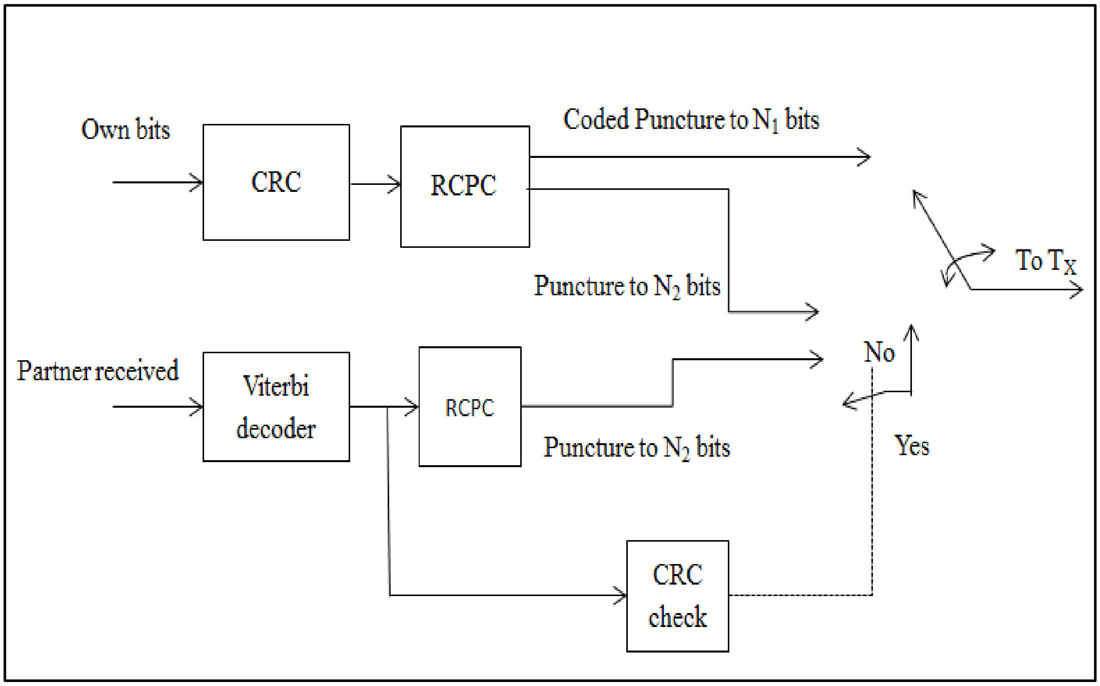


Figure 2. 5: Coded Cooperation block diagram [1]

The working of coded cooperation scheme as follows:

1. The user's data in coded cooperation is encoded and it is dividing into two segments. Consider the partitioned bits are N_1 and N_2.
2. Let $N1+N_2$is original code word, it is puncture N_1 and N_2bits.
3. The total data stream is divide into two blocks, are called *frames*.
4. In first frame, user sends its own data i.e. in N_1bits and in second frame it transmits its partner's data N_2 bits respectively.
5. Whenever the cooperation is not possible the user transmits its own data in second frame also.
6. The cooperation level by using coded cooperation is defined by N_2/N.

2.3 Combining Type

Combining techniques are used to combine the multiple received signals from each channel at the receiver. All the combine signals are become into a single improved signal.

2.3.1 Equal Ratio Combining (ERC)

This is the easiest combining technique; in this all received signals are just added together [16].

$$y_d = y_{s,d}[n] + y_{r,d}[n] \tag{2.3.1}$$

Here $y_{s,d}$ is the information received at the receiver from source, and $y_{r,d}$ is the received signal from relay.

2.3.2 Fixed Ratio Combining (FRC)

Unlike ERC, they are weighted with a constant ratio. It gives a much better performance than the Equal ratio combining. The ratio represents the average channel characteristics over a period of time and hence does not take into effect the temporary influence due to fading or other parameters [16]:

$$y_d[n] = \sum_{i=1}^{K} d_{i,d} \cdot y_{i,d}[n] \tag{2.3.2}$$

For single relay case:

In single relay case, only one source, relay and one destination is present [16]

$$y_d[n] = d_{s,d} \cdot y_{s,d}[n] + d_{s,r,d} \cdot y_{r,d}[n] \tag{2.3.3}$$

here

$d_{s,d}$ is the direct link weight from source to destination

$d_{s,r,d}$ is the multi-hop link.

2.3.3Signal to Noise Ratio Combining (SNRC)

SNRC gives a superior performance by intelligently weighting the incoming signals. Here SNR is used to weight the received signals. SNRC is given as [16].

$$y_d[n] = \sum_{i=1}^{K} SNR_i . y_{i,d}[n]$$

(2.3.4)

For single relay case:

In single relay case, only one source, one destination and cooperative agent called relay n is present [16].

$$y_d[n] = SNR_{s,d} y_{s,d}[n] + SNR_{s,r,d} y_{r,d}[n]$$

(2.3.5)

$SNR_{s,d}$ represents the direct link SNR and $SNR_{s,r,d}$ denotes the overall of multi hop channel. Thus, sending an additional sequence, results in the certain loss of the bandwidth.

2.3.4 Maximal Ratio Combining (MRC)

In this method the signals from all the multiple nodes are weighted at the receiver by individually according to their voltage to noise power ratio and then combined. This MRC technique carry out the best performance by multiplying conjugated channel gain to each received signal. This assumes perfect CSI is known at the receiver [17].

$$y_d[n] = \sum_{i=1}^{K} h^*_{i,d} . y_{i,d}[n]$$

(2.3.6)

For single relay case:

$$y_d[n] = h^*_{i,d} . y_{s,d}[n] + h^*_{i,d} . y_{r,d}[n]$$

(2.3.7)

2.3.4 Selection combining (SC)

In this technique all the multiple copies of the original message are combined at the destination. But the receiver picks the signal, which has the largest signal-noise-ratio (SNR).

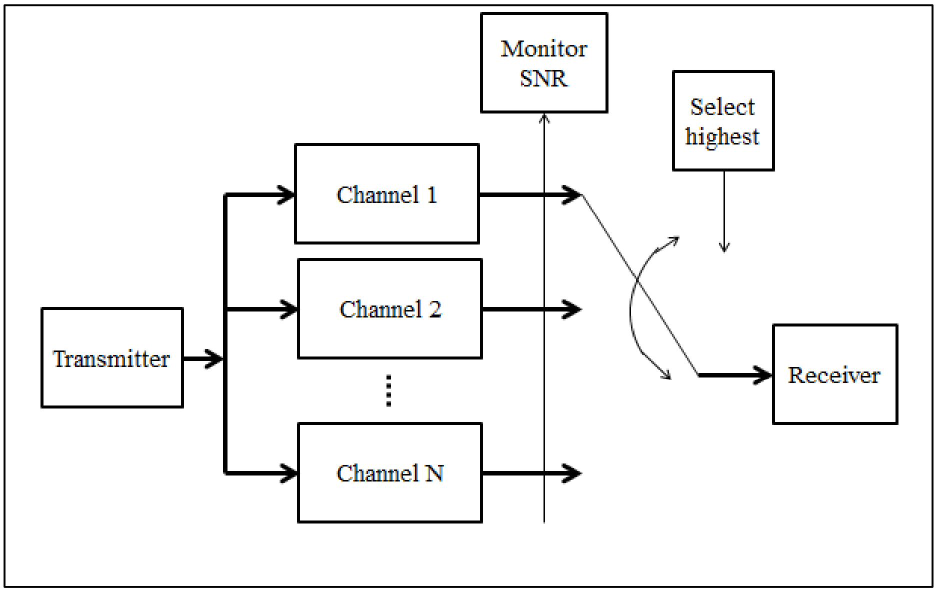


Figure 2. 6: Selection combining [16]

2.4 Power allocation in cooperative relaying

Cooperation is available in wireless networks, where the multiple nodes are helping each other by relaying transmission. Cooperative network consists of source, destination and *n*-number of relays.

In cooperative communication, all the relays are helpful to transmit the information from source to destination. The total power in this system is equally dived to source and relays, such type of power allocation is referred as equal power allocation (EPA). Power allocation in cooperative communication by knowing the channel gains is optimal power allocation (OPA). OPA method is further done by water filling process. The optimum power allocation has many advantages for improve the system performance in terms of low SER, high throughput and low probability of error [24]. In wireless environment number of relays are present for this the power allocation process is manipulated, in this scheme the system select the best relay among the multiple relays and then allocate power to the relay on assumption of mean channel gains [25]. In this power allocation is done by two steps. In step-I, the power of source is balanced for overall network. In stage-II, power allocated for selected relays equally [25].

The power allocation schemes are further done by some soft computing techniques. Conventional requires an exactly analysis model and a lot of computational time. Unlike, conventional the soft computing techniques are liberal of uncertainty, partial truth and approximation. Genetic Algorithm (GA) for adaptive power allocation in cooperative communication to minimize the SER and outage probability. And this type of power allocation is developed for relay selection also [26]. In this type of power allocation the soft computing techniques are optimized the power allocation factor in fitness function. Here the source power and relay power are taken as constrains for fitness function. After evaluating the fitness function the power of source and relay are allotted by optimum value.

PSO (Particle Swarm Optimization) based power allocation also improves the system performance in terms of outage and SER. Unlike GA, PSO does not have any evolutionary operations such as, cross over and mutation. In PSO particles are updated themselves with the internal velocity. It is easy to implement and it provides quick convergence to optimum solution. The PSO provides an algorithm to evaluate the fitness function for the system. Here also the source power and relay power are taken as constrains for fitness function. PSO technique is based on moment of the swarm and the reason behind using particle swarm optimization is, it is very simple to implement and fast convergence for good optimum solution [27].

Chapter 3

SYSTEM MODEL

SYSTEM MODEL

3.1 System Model

In this research, a cooperative network with single and multi-relay as shown in Fig.3.1 and 3.2, it contains a source which is transmitting information to a destination through cooperating relay is considered. Here the considered cooperation scheme is amplify and forward (AF) relaying. The link is independent and flat Rayleigh fading [18]. Basically there are two phases of operation.

The source sends information to the destination and relay receives the information from source at the same time in first phase. The signals received at destination and relay $y_{s,d}$, are [18].

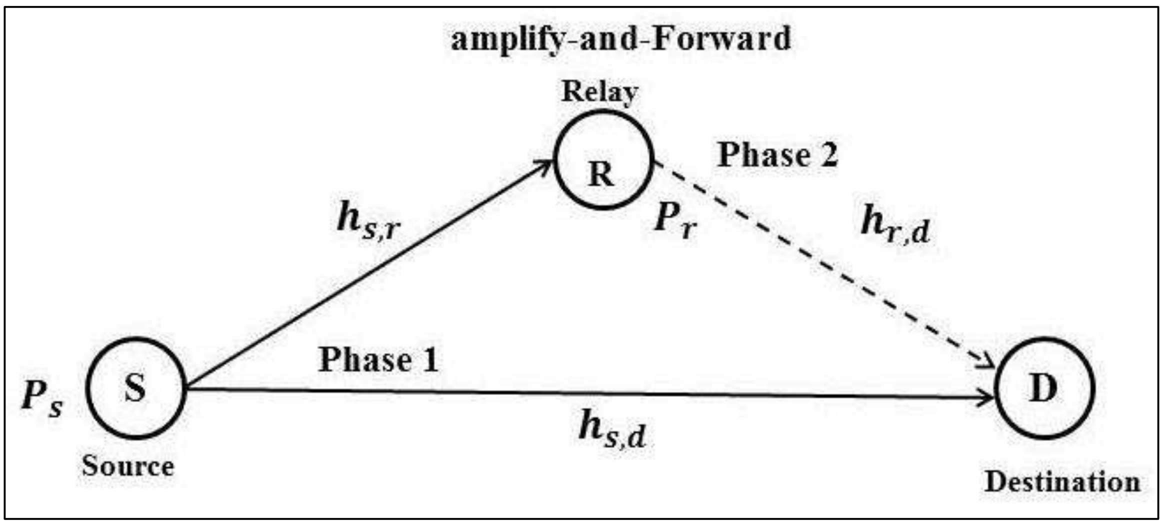


Figure 3. 1 AF single relay cooperative relaying [18]

$$y_{s,d} = \sqrt{p_S} h_{s,d} .x[n] + z_{s,d}[n]$$

(3.1.1)

$$y_{s,r_i} = \sqrt{p_S} h_{s,r_i} .x[n] + z_{s,r_i}[n]$$

(3.1.2)

Where $x[n]$ the information is transmitted from source, p_s is the source power, the channel coefficients is given by [18].

$$h_{s,d} = d_{s,d} \cdot a_{s,d}[n],\ h_{s,r_i} = d_{s,r_i} \cdot a_{s,r_i}[n]$$

Here $a_{s,d}[n], a_{s,r}[n]$, are the random variable with variances $\delta^2_{s,d}$, $\delta^2_{r_i,d}$. $z_{s,d}[n]$, $z_{s,r_i}[n]$ are AWGN noises. Here $d_{s,d}$, d_{s,r_i} are the distances from soure to destination and relay nodes respectively.

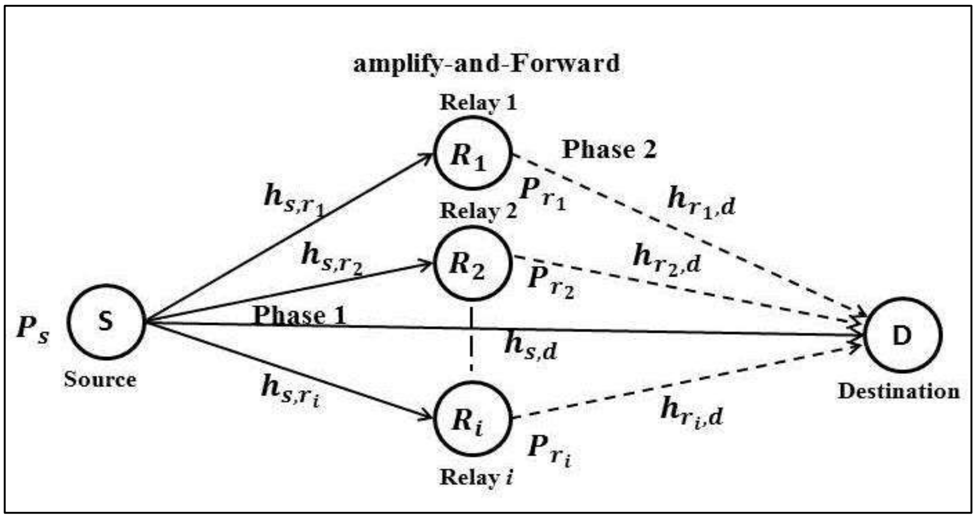


Figure 3. 2: AF multi-relay cooperative network [13]

The relay amplifies the data in second phase, which is received from the source (including noise amplification) and transmits to its receiver. p_r is relay power .The received information at destination is expressed by[13]:

$$y_{r_i,d} = \frac{\sqrt{p_{r_i}}}{\sqrt{p_s \left| h_{s,r_i} \right|^2 + N_0}} h_{r_i,d}[n].y_{s,r_i} + z_{r_i,d}[n]$$

(3.1.3)

Here i=1, 2, 3…….n relays

Where $h_{r_i,d}$ is relay to destination channel coefficients. P_r is the transmitted power at the relay node. $h_{r_i,d} = d_{r_i,d} . a_{r_i,d}[n]$, $a_{r,d}[n]$ is with variance $\delta^2_{r_i,d}$. $z_{r,d}$ is AWG noise. The distance the relay and destination is denoted as $d_{r_i,d}$. The transmitted information, its power is normalized. $\delta^2_{s,d}$, δ^2_{s,r_i} and $\delta^2_{r_i,d}$ are taken as1.

3.2 PERFORMANCE ANALYSIS OF AF COOPERATIVE RELAYING

3.2.1 SER performance analysis

In AF, the relay amplifies and transmits the information which is received from the source. At the destination the multiple copies of information is combined. The output at the receiver by MRC detector with knowledge of channel state information (CSI) is expressed as [15].

$$y_d = a_s y_{s,d} + \sum_{i=0}^{N} a_i y_{r_i,d} \tag{3.2.1}$$

Where

$$\alpha_s = \sqrt{p_s} h_{s,d} / N_0 \quad \text{and}$$

$$\alpha_i = \frac{\sqrt{\dfrac{p_s \cdot p_{r_i}}{p_s \left| h_{s,r_i} \right|^2 + N_0}} h_{s,r_i} h_{r_i,d}}{\left(\dfrac{p_{r_i} \left| h_{r_i,d} \right|^2}{p_s \left| h_{s,r_i} \right|^2 + N_0} + 1 \right) N_0}$$

where i=1, 2, 3…n (relays)

Assume the transmitted information $x[n]$ then the SNR is expressed at the receiver by MRC detector as [15].

$$SNR_d = \gamma_s + \sum_{i=1}^{N} \gamma_i$$

(3.2.2)

where

$$\gamma_s = P_0 \left| h_{s,d} \right|^2 / N_0 \qquad \text{and}$$

$$\gamma_i = \frac{1}{N_0} \frac{P_0 . P_i \left| h_{s,r_i} \right|^2 \left| h_{r_i,d} \right|^2}{P_0 \left| h_{s,r_i} \right|^2 + P_i \left| h_{r_i,d} \right|^2 + N_0}$$

SER on channel state information is expressed below

SER for M-PSK modulation, with instantaneous SNR γ with the CSI is given by [15]

$$P_{CSI}^{PSK} = \psi_{PSK}(\gamma) \triangleq \frac{1}{\pi} \int_0^{(M-1)\pi/M} \exp\left(-\frac{b_{psk}\gamma}{\sin^2(\theta)} \right) d\theta$$

(3.2.3)

Where $b_{psk} = \sin^2(\pi / M)$

SER for M-QAM modulation, with instantaneous SNR γ with the CSI is given by

$$P_{CSI}^{QAM} = \psi_{QAM}(\gamma) \triangleq 4CQ(\sqrt{b_{QAM}\gamma}) - 4C^2 Q^2 (\sqrt{b_{QAM}\gamma})$$

(3.2.4)

In which $C = 1 - 1/\sqrt{M}$ and $b_{QAM} = 3/(M-1)$

Let us the random variable Z and its MGF is given by:

$$M_Z(s) = \int_{-\infty}^{\infty} \exp(-sz) P_Z(z) dz$$

(3.2.5)

Averaging the SER on the Rayleigh fading channel, for M-PSK and M-QAM the SER expressed, as [15].

$$P_{SER} \approx \int_0^{(M-1)\pi/M} M_{\gamma s}\left(\frac{b_{PSK}}{\sin^2\theta}\right)\prod_{i=1}^{N} M_{\tilde{\gamma} i}\left(\frac{b_{PSK}}{\sin^2\theta}\right)d\theta$$

(3.2.6)

$$P_{SER} \approx \frac{4C}{\pi}\int_0^{\pi/2} M_{\gamma s}\left(\frac{b_{QAM}}{2\sin^2\theta}\right)\prod_{i=1}^{N} M_{\tilde{\gamma} i}\left(\frac{b_{QAM}}{2\sin^2\theta}\right) - \frac{4C^2}{\pi}\int_0^{\pi/4} M_{\gamma s}\left(\frac{b_{QAM}}{2\sin^2\theta}\right)\prod_{i=1}^{N} M_{\tilde{\gamma} i}\left(\frac{b_{QAM}}{2\sin^2\theta}\right)$$

(3.2.7)

Here we are using the $\tilde{\gamma}_i$ as SNR approximation instead of γ_i. For exponential random variables the MGF of γ_s is given by

$$M_{\gamma s} = \frac{1}{1+\dfrac{sP_0\sigma^2{}_{s,d}}{N_0}}$$

(3.2.8)

For obtaining the MGF of $\tilde{\gamma}_i$,Let us consider two independent random variables X_1 and X_2 with parameters β_1 and β_2 , and the harmonic mean of X_1 and X_2 is given by $Z = \frac{X_1 X_2}{X_1 + X_2}$, the MGF is given by:

$$M_Z(s) = \frac{(\beta_1-\beta_2)^2+(\beta_1+\beta_2)^2}{\Delta^2} + \frac{2\beta_1\beta_2}{\Delta^3}\ln\frac{(\beta_1+\beta_2+s+\Delta)^2}{4\beta_1\beta_2}$$

(3.2.9)

where

$$\Delta = \sqrt{(\beta_1 - \beta_2)^2 + 2(\beta_1 + \beta_2)s + s^2}$$

here $\beta_1 = N_0 / P_0 \sigma^2{}_{s,r_i}$ and $\beta_2 = N_0 / P_i \sigma^2{}_{r_i,d}$. At high SNR, for any relay $\beta_1 = \beta_2 = 0$ and $\Delta = s$, thus the MGF of equation (3.2.9) is approximated as:

$$M_Z(s) \approx \frac{\beta_1 + \beta_2}{s} + \frac{2\beta_1\beta_2}{s^2} \ln \frac{s^2}{\beta_1\beta_2}$$

(3.2.10)

At enough SNR, the simplified MGF is expressed as:

$$M_Z(s) \approx \frac{\beta_1 + \beta_2}{s}$$

(3.2.11)

Substituting the equation (3.2.11) in (3.2.6) we get the following result (3.2.12).

3.3.2 Asymptotically approximation

The closed form of SER is difficult to derive from the above and it is very complex. Hence the asymptotic performance is evaluated by using SER approximation.

Theorem 3.3.1: At high SNR, assume all channel links are available and the variances are not equal to zero, then the *M*-QAM or *M*-PSK signals by approximated as [15]:

$$SER = \frac{g(N) N_0^{N+1}}{b^{N+1}} \frac{1}{P_s \delta_{s,d}^2} \prod_{i=1}^{N} \left(\frac{1}{P_s \delta_{s,r_i}^2} + \frac{1}{P_{r_i} \delta_{r_i,d}^2} \right)$$

(3.2.12)

For M-PSK signals: $b = b_{PSK}$ and

$$g(N) = \frac{1}{\pi}\int_0^{(M-1)\pi/M} \sin^{2(N+1)} \theta d\theta$$

(3.2.13)

For M-QAM, $b = b_{QAM} \big/ 2$ and

$$g(N) = \frac{4C}{\pi}\int_0^{\pi/2} \sin^{2(N+1)} \theta d\theta - \frac{4C^2}{\pi}\int_0^{\pi/4} \sin^{(N+1)} \theta d\theta$$

(3.2.14)

For *M*-PSK,

$$b = \sin^2(\pi / M)$$

$$g(N) = \frac{3(M-1)}{8M} + \frac{\sin(\frac{2\pi}{M})}{4\pi} - \frac{\sin(\frac{4\pi}{M})}{32\pi}$$

(3.2.15)

3.3 Power allocation using PSO

In this thesis, a Particle Swarm Optimization (PSO) algorithm is using for power allocation in amplify-and-forward cooperative network using single and multi-relay is proposed. First we allocate power to system using equal power, means total power P is taken as 1. The power is allocated to source as $P_S = P/2$ and $P_r = P/2$, after that the system performance is compared with PSO power allocation system performance.

3.3.1 Particle Swarm Optimization

Particle Swarm Optimization is optimizing technique; it gives the best optimum value for a given problem by using objective function. PSO contains a swarm of particles, each particles in this swarm gives a possible solution. This optimizing technique is working based on the population search, and gives a best solution by iteration method [19-21].

In PSO algorithm, all particles are move towards its optimum value. For each iteration all the particles in this swarm are updated by its position and velocity for optimization ability. In PSO each particle maintains its position evaluated fitness and velocity. The velocities of the n-particles are updated by using below equation [20]:

$$v_n(t+1) = \omega v_n(t) + c_1 r_1 [y_n(t) + p_n(t)] + c_2 r_2 [\hat{y}(t) - p_n(t)]$$

(3.3.1)

Where $r_1(t)$ and $r_2(t)$ are random variables , elements are equally dispense in [0, 1].Let $p_n(t)$ denotes the n particles position in the m_x - search space at time t. By updating velocity $v_n(t+1)$ to current position, the particles position are changed, it is given by [20].

$$p_n(t+1) = p_n(t) + v_n(t+1)$$

(3.3.2)

In PSO algorithm individual fitness and it is achieved its fitness, called as personal best position (*pbest*). Compare each particles pbest value with the current pbest value. If the current value is better than pbest, update that value is current pbest value. Compare fitness evolution for overall particles with previous gbest. If the current gbest is better than gbest, update that value is gbest. The algorithm repeated until some stopping condition met, usually a maximum number of iterations [19]. PSO algorithm at last maintains the best value among all particles as global best value (*gbest*).

3.3.2 Problem statement

The tight approximation of SER for the *M*-PSK or *M*-QAM signals as: 3.2.12

$$SER = \frac{BN^2}{b^2} \frac{1}{P_s \delta_{s,d}^2} \prod_{i=1}^{N} \left(\frac{1}{P_s \delta_{s,r_i}^2} + \frac{1}{P_{r_i} \delta_{r_i,d}^2} \right)$$

(3.3.3)

Here the problem statement is, Minimize *SER* (Equation: 3.2.5)

Such that:

$P_S = \alpha P$

$$P_{r_i} = (1-\alpha) P \text{; } (\alpha\text{= power allocation factor})$$

where $$0 < \alpha < 1$$

$$p_S + \sum_{i=1}^{N} p_{r_i} = P_{total}$$

(3.3.4)

For single relay case:

$$p_S + p_r = P_{total}$$

(3.3.5)

3.3.3 Flow chart of PSO

In this work, PSO based power allocation algorithm for single and multi-relay AF cooperative network is proposed. The figure 3.3 depicts the flowchart of PSO algorithm.

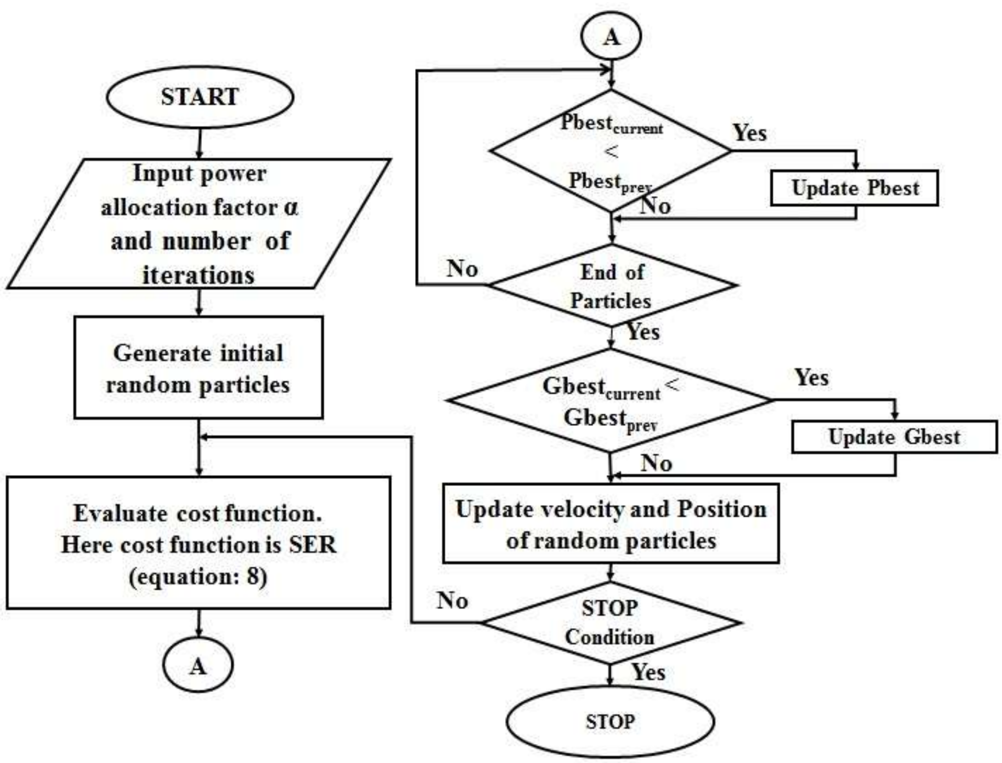


Figure 3. 3 Flow chart of PSO algorithm for minimizing SER

PSO algorithm simply evaluates the fitness function and obtains its optimal solution. Here fitness function is SER equation (3.3.3), by using PSO we have evaluate the SER expression and find out the solution for minimize the symbol error rate. For each iteration all the particles are evaluated using the objective function and find out the solution of that cost function.

In algorithm, initially we take random particles for optimization by using fitness function. Here the fitness function is SER expression (3.2.5) of AF system model. For each iteration all the random particles in the swarm are try to get the optimum value. Each individual fitness and its achieved fitness in the next iteration are referred as individual best position or personal best position (*pbest*).Compare each particles pbest value with the current pbest value. If the current value is better than pbest, update that value is current pbest value. The algorithm repeats until maximum iterations achieved. The best value among the all particles is refereed as global best value (*gbest*).

Figure 4.2 shows the convergence of PSO. Here 20 particles and 50 iterations are considered to achieve the optimum value. The position and velocity of each particle is derived for each iteration. After completion of all iterations, the algorithm finds the optimum value that is nearest. After 50 iterations it reached its optimum value figure 4.2 shows the convergence of particle swarm optimization (PSO).

Chapter 4

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

MATLAB software is used for computer simulation. The system model using amplify-and-forward protocol is simulated by Mat Lab. The system model has source, multi-relays and destination. First the simulation is performed for single relay case, means N=1. After that the simulation is performed for multi-relay model. The total transmitted power P_t=1W and it is allocated to source and relay power as P_s=0.5W, P_r=0.5W each.

<u>Simulation Parameters</u>:

Parameters	Specification
Number of bits	10^4
Bits per symbol	2
source	1
relays	1, 3
destination	1
Combining strategy	Maximal ratio combining
Channel	Rayleigh
Modulation	QPSK

Table 1 Simulation parameters

The SER performance of AF based cooperative network using single relay, using equal power allocation is described below. Figure 4.1 gives a SER performance analysis for AF relaying using equal power allocation and QPSK modulation. Result is compared with theoretical results for QPSK modulation with AWGN and Rayleigh fading channel.

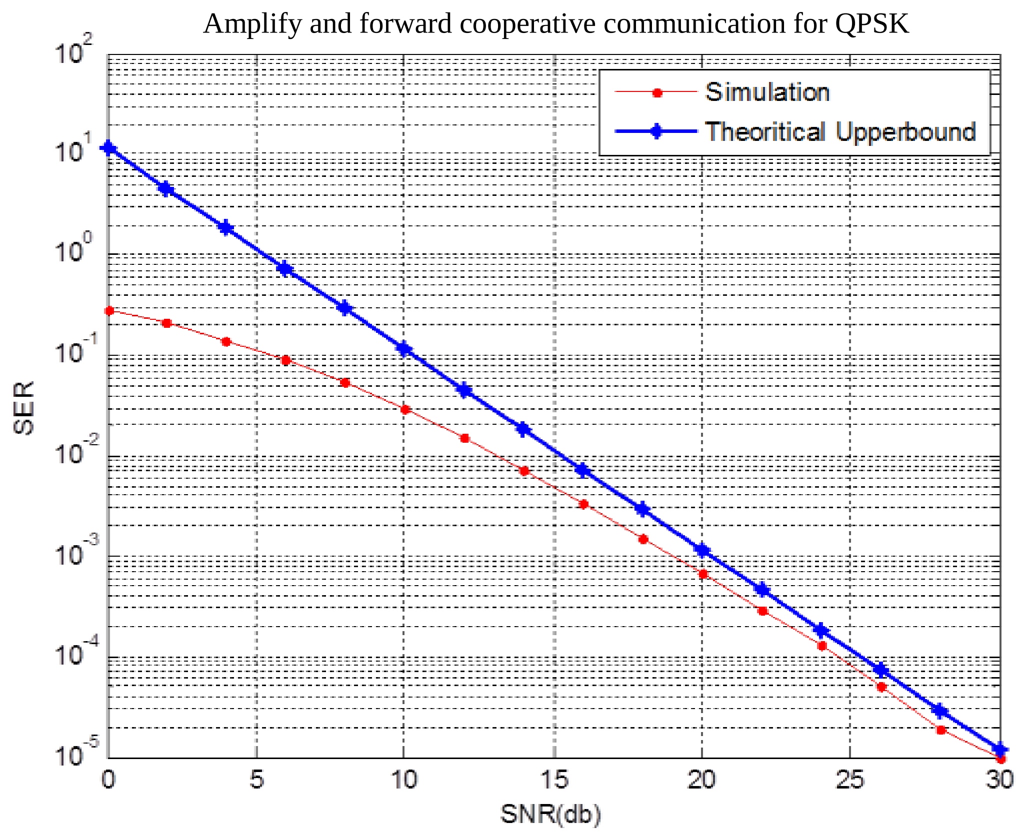


Figure 4.1 SER v/s SNR for AF

From the figure 4.1, it is clear that, the simulation result shows that it achieve better performance compared with theoretical SER for amplify and forward relaying scheme.

<u>SER performance analysis using PSO power allocation:</u>

Figure 4.2 shows, the convergence analysis of PSO algorithm. We consider 20 particles and 50 iteration to achieve the optimum point. The PSO algorithms using its fitness function for obtain optimum solution. Here SER expression (equation 3.2.5) is fitness function. In this fitness function we allocate the powers, $P_S = \alpha P$ and $P_r = (1-\alpha)P$. Where α is a power allocation factor. The position and velocity of the particles are updated for each iteration. After completion of all iterations, the PSO algorithm gets the optimum value that is nearest. After 50 iterations it reached its optimum value, figure 4.2 shows the convergence of particle swarm optimization (PSO).

<u>Simulation parameters:</u>

PSO Parameters	
Population	20
PSO Iteration	50

Table 2 PSO parameters

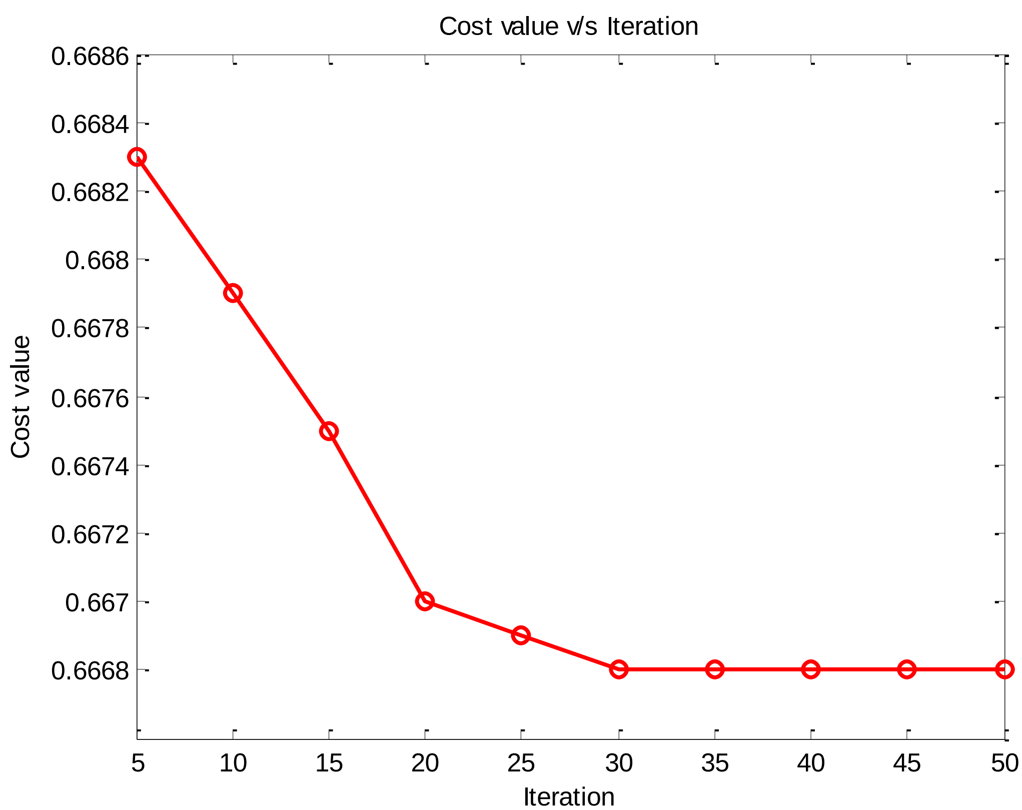


Figure 4. 2 Convergence of PSO (cost value v/s iterations)

From the convergence plot it is clear that the optimum point is obtain by using particle swarm optimization is 0.6668. Then the power allocation factor α =0.6668. The power values is obtained as $P_S = 0.6668P$ and $P_r = 0.3332P$.

The SER performance using PSO power allocation by allocating the source and relay powers as $P_S = 0.6668P$, $P_r = 0.3332P$ is shown in figure 4.3.

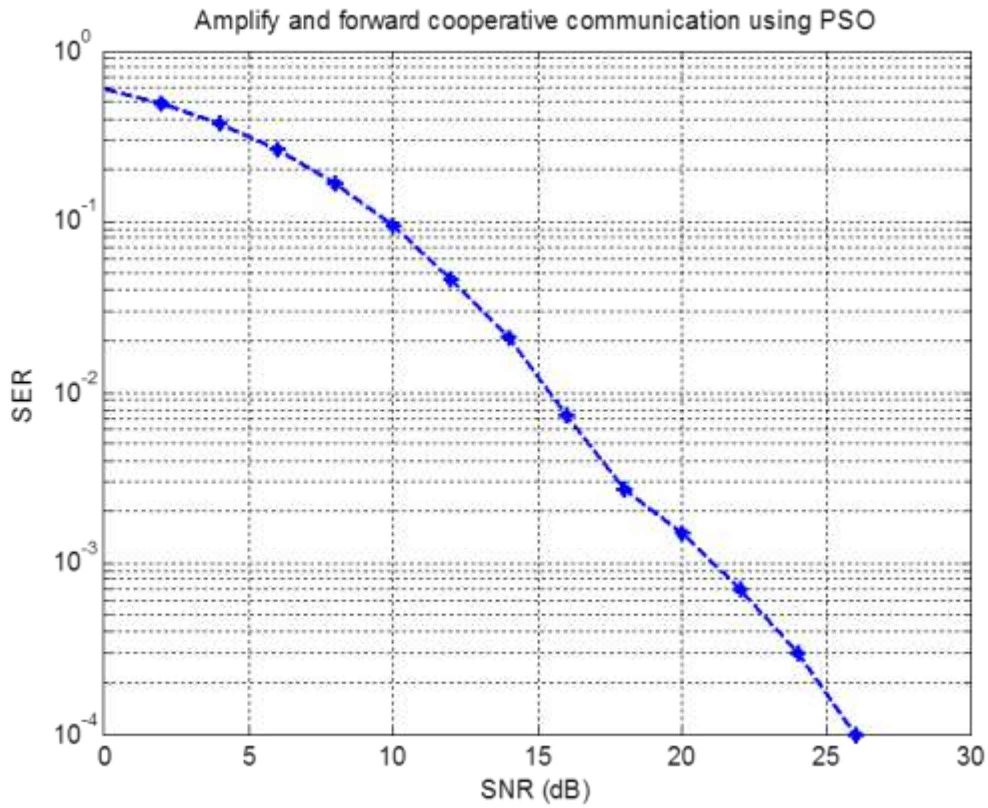


Figure 4.3 SER v/s SNR for AF single relay using PSO power allocation

Now the PSO based power allocation system performance is compared with equal power allocation. For the PSO based power allocation, power values are $P_s = 0.6668P$ and $P_r = 0.3332P$ by equation 3.2.5. Figure 4.4 shows SER performance versus SNR for the proposed PSO based power allocation scheme ("PSO PA") and equal power allocation scheme for single relay AF cooperative communication system. In this case we observe that at constant SNR, the proposed PSO based PA achieves better SER performance than that of the equal power allocation with low complexity.

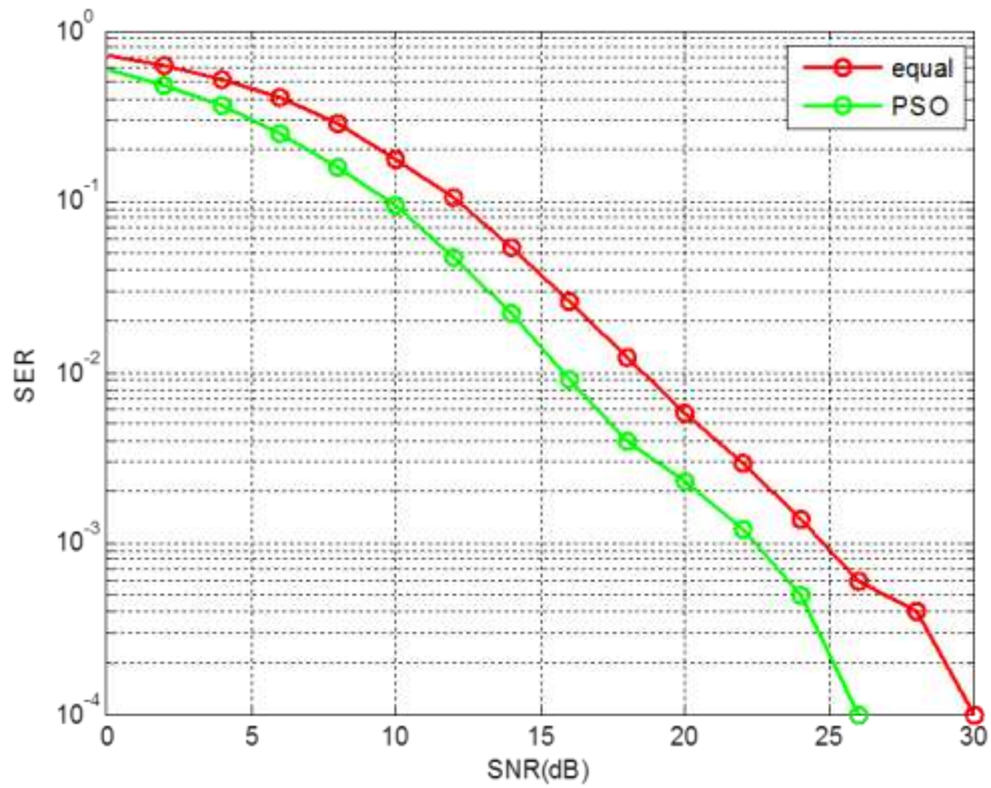


Figure 4.4 Comparison of Equal and PSO power allocation for AF relay model

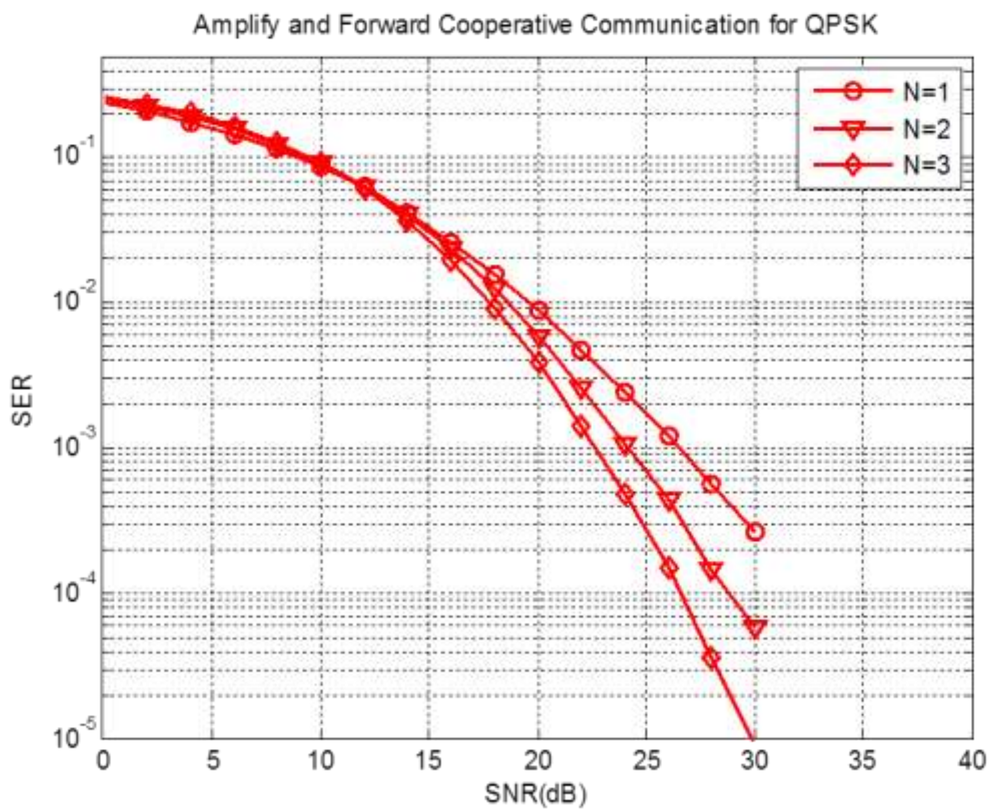
The performance analysis comparison of equal and PSO and GA algorithm is given below. From the comparison it is clear that, the prosed power allocation achieves better performance than equal and GA power allocation.

Power Allocation (PA)	**5dB (SNR)**	**10dB (SNR)**	**15dB (SNR)**	**20dB (SNR)**	**25dB (SNR)**
EPA (SER)	$10^{-0.3}$	$10^{-0.9}$	$10^{-0.7}$	$10^{-2.5}$	$10^{-3.2}$
PSO PA (SER)	$10^{-0.8}$	$10^{-1.1}$	$10^{-2.0}$	$10^{-2.9}$	$10^{-3.9}$
GA PA (SER) [26]	$10^{-0.4}$	$10^{-1.0}$	$10^{-1.7}$	$10^{-2.6}$	$10^{-3.6}$

Table 3. SNR v/s SER comparison for equal, PSO and GA

PSO based power allocation for AF multi-relay cooperative network:

The multi-relay AF network contains one source, *N* relays and one destination is simulated using PSO based power allocation, after that its performance is compared with the equal power allocation case. Here the information received from source is transmitted to the destination by the relays. The multiple copies of information are combined at receiver by MRC. The modulation used here is QPSK. Here we analyzing up to 3 relays, means N=3.The SER performance of PSO based power allocation for AF multi-relay cooperative network is shown in figure 4.5.



Figures 4.5 SER v/s SNR for AF multi-relay using PSO power allocation

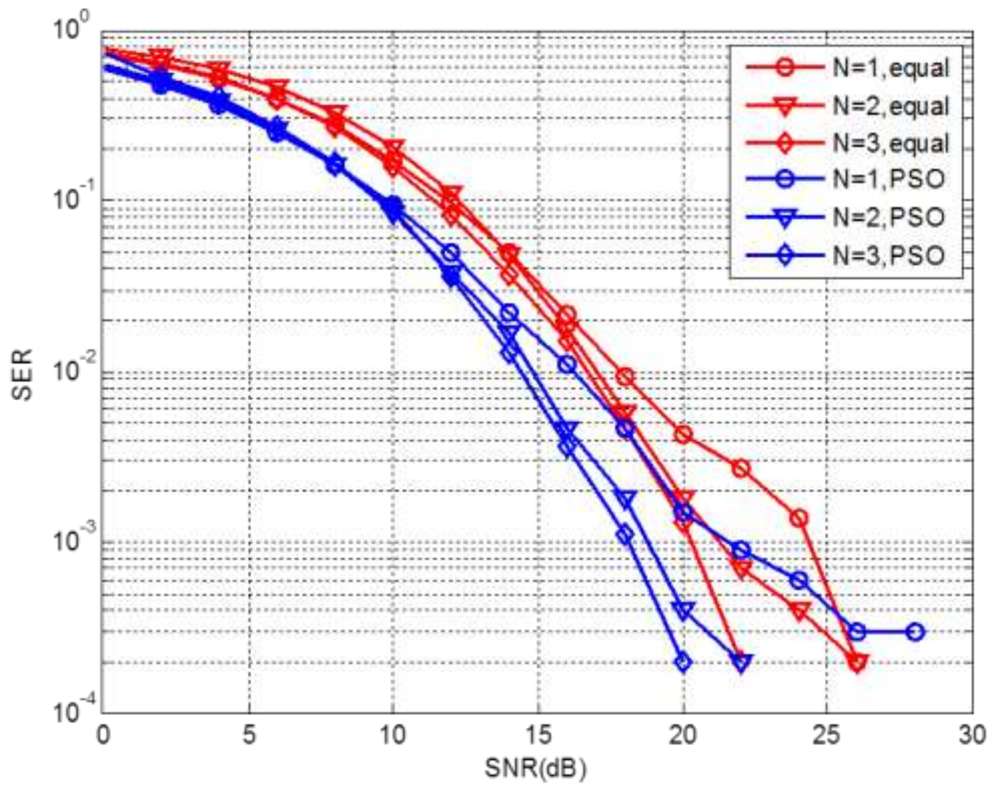


Figure 4. 6 Comparison of Equal and PSO power allocation for AF multi-relay model

The PSO power allocation system performance is compared with equal power allocation system performance. Figure 4.6 describes the performance analysis of PSO power allocation and equal power allocation scheme for multi-relay AF cooperative communication system. In this case we observe that at constant SNR, the proposed PA achieves better SER performance than that of the equal power allocation with low complexity.

Summary of simulation results

1. SER performance analysis for AF cooperative relaying scheme is simulated, and it is compared with theoretical values. The simulation results achieved better performance compared to theoretical calculation.

2. The proposed PSO power allocation is applied to AF cooperative relaying and compared with system performance with equal PA. In this case the source and relay power values are:

Power Allocation (PA)	P_s	P_r
Equal PA	0.5P	0.5P
PSO PA	0.6668P	0.3332P

3. PSO based power allocation is also applied for multi-relay AF cooperative network. The simulation result is compared with equal PA system performance. In this case the power of source and relays are:

Power Allocation (PA)	P_s	P_{r_1}	P_{r_2}	P_{r_3}
Equal PA	0.25P	0.25P	0.25P	0.25P
PSO PA	0.6668P	0.1110P	0.1110P	0.1110P

Chapter 5

CONCLUSION AND SCOPE OF FUTURE WORK

CONCLUSION AND SCOPE OF FUTURE WORK

Cooperative diversity has many advantages to increase the wireless communication system performance, in terms of lower SER (symbol error rate) and lower outage. The cooperative communication system is simulated for amplify-and-forward protocol; maximal ratio combiner is used to combine the multiple copies of the original message at the receiver.

The performance AF protocol has been analyzed for single relay and multi relay cases in Rayleigh fading channel. The SER performance analysis of AF relaying scheme using single and multi-relay case with equal power allocation is analyzed.

From the simulation results, it is observed that he system performance is improves, whenever the number of relays increases. By this way the problems of wireless communication system like fading, shadowing and path-loss are reduced by using relay as a third station. Hence the information is transmitted in the form of multiple copies of signals and it is combined at the receiver by using combining techniques.

The proposed power allocation scheme is applied to cooperative communication system by using Particle Swarm Optimization (PSO) for amplify-and-forward for single and multi-relay on Rayleigh fading channel. The SER performance analysis is analyzed for amplify-and-forward for single as well as multi-relay. After that the simulation results are compared with amplify-and-forward cooperative communication using equal power allocation.

Minimizing SER (symbol error rate) is defines as optimization problem with source and relay power as constraints. Here both source and relay powers are function of power allocation factor. The performance analysis between equal, PSO and GA is compared. From the simulation result of PSO it is clearly observed that PSO based power allocation achieves better performance compared to equal power allocation.

The scope of future work is relay selection, in wireless environment many relays are present it is necessary to select the relay from multiple relays to transmit the data from source to the destination and allocate power to selected relays.

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